Enhancement of high resolution hydrological modeling on the CONUS HRAP grid using operational NOAA NCEP and NOAA OHD models

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Statement of Work

This new study builds on a prior NCEP/OHD 4km CONUS modeling effort. It has three main components which together provide a comprehensive suite of modeling-related improvements enabling improved hydrological and land surface forecasts and analyses, investigations into land-atmosphere interactions, and improved support of drought monitoring activities. Specific tasks include:

Current Research Focus

I. Model Support-Related Improvements
- Improved downscaling of 1/8th degree NLDAS forcing to 4km HRAP grid
- Enhanced spin-up strategies for retrospective and real-time simulations

II. Model Component Improvements
- Improved snow assimilation modules for Noah and SAC-HTET/Snow17
- High-resolution routing capability for Noah and SAC-HTET in LIS
- Testing of NOAA ET physics in new SAC-HTET model
- Testing of improved sub-surface runoff modeling in SAC-HTET
- Integration of dynamic parameter calculation module into Snow17
- Enhanced Noah bundle upgrades including snow albedo, ground water treatment.

III. Model Output
- Production of 31-year 4km retrospective SAC-HTET/Noah simulations
- Validation of model output
- Operational application of retrospective simulations
- Integration of long term model climatology data into drought monitoring activities

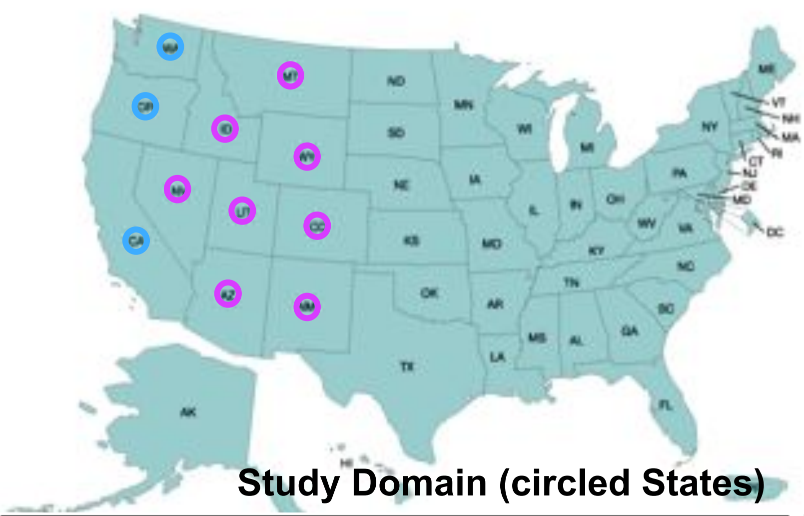
Deliverables Schedule

	2011	2012		2013		2014
	JASOND	JFMAMJJASOND		JFMAMJJASOND		JFMAMJ
Improve downscaling of NLDAS forcing						
Develop a statistical regression model of lapse rate						
Implement/test the derived lapse rate model						
Verify the downscaling results						
Enhance the spin-up strategy						
Upgrade the spin-up strategy for retrospective runs						
Investigate factors affecting the spin-up efficiency						
Tests to generate the optimal ICs						
Assimilate MODIS snow cover into land models						
Improve snow assimilation modules						
Process 500m MODIS SCA onto the HRAP grid						
Implement/test the error schemes						
Perform assimilation and verify the results						
Integrate/test SAC-HTET/Snow17 improvements						
Integrate/test Noah model improvements						
Implement/test the OHD routing code in LIS						
Generate/verify 33-year retrospective products						
Operational application of retrospective simulations including support of drought monitoring activities						
Quarterly coordination meetings						
Bi-annual reports						
Publications (2-3)						
Final Report						

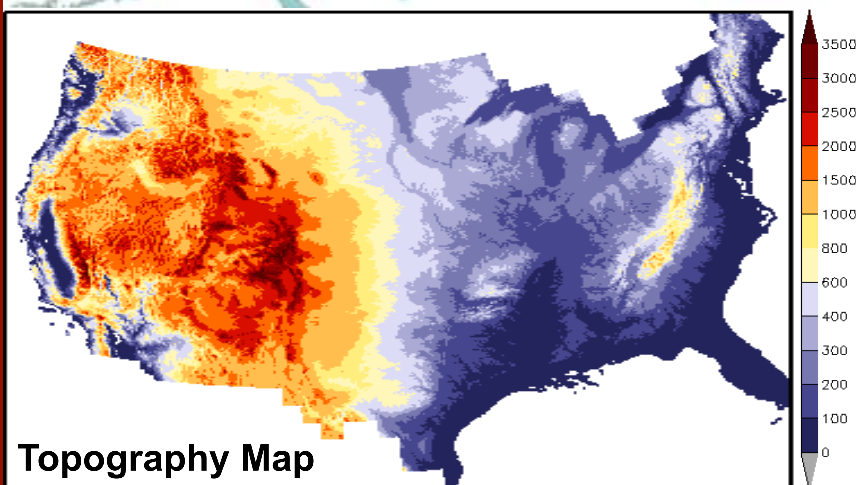
Degree of shading denotes activity on each sub-task

Preliminary Studies

Data and Study Regions



Study Domain (circled States)



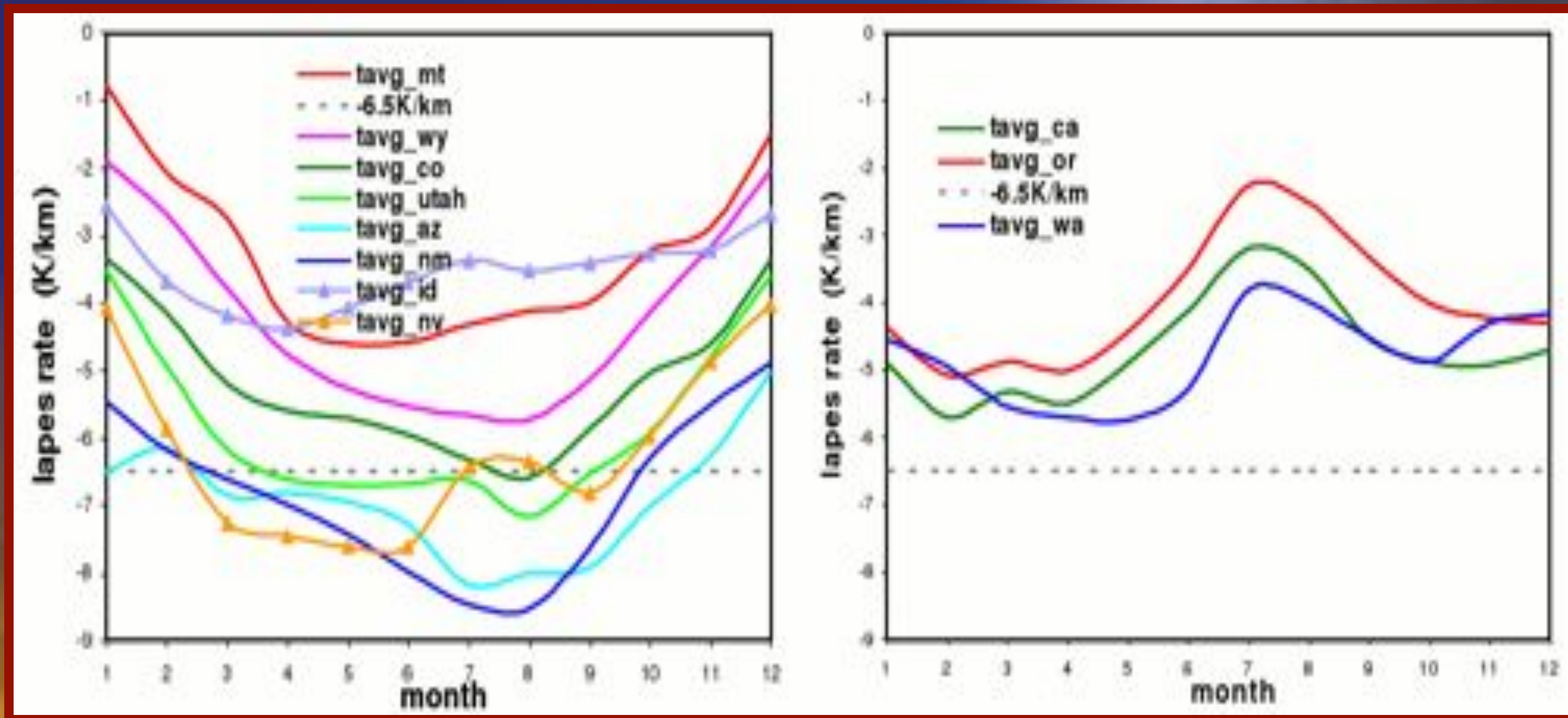
Topography Map

Station numbers in each state

	SNOTEL	USHCN	TOTAL
AZ	15	19	34
CA	32	50	82
CO	99	25	124
ID	82	21	103
MT	90	35	125
NM	21	24	45
NV	27	12	39
OR	75	36	111
UT	87	38	125
WA	59	33	92
WY	82	26	108
TOTAL	670	319	989

Daily Mean/Max/Min Temperature and Elevation Data in project from drawn from (1) U. S. Historical Climatology Network (USHCN) and (2) SNOTEL

Spatial and Temporal Variability of Lapse Rate



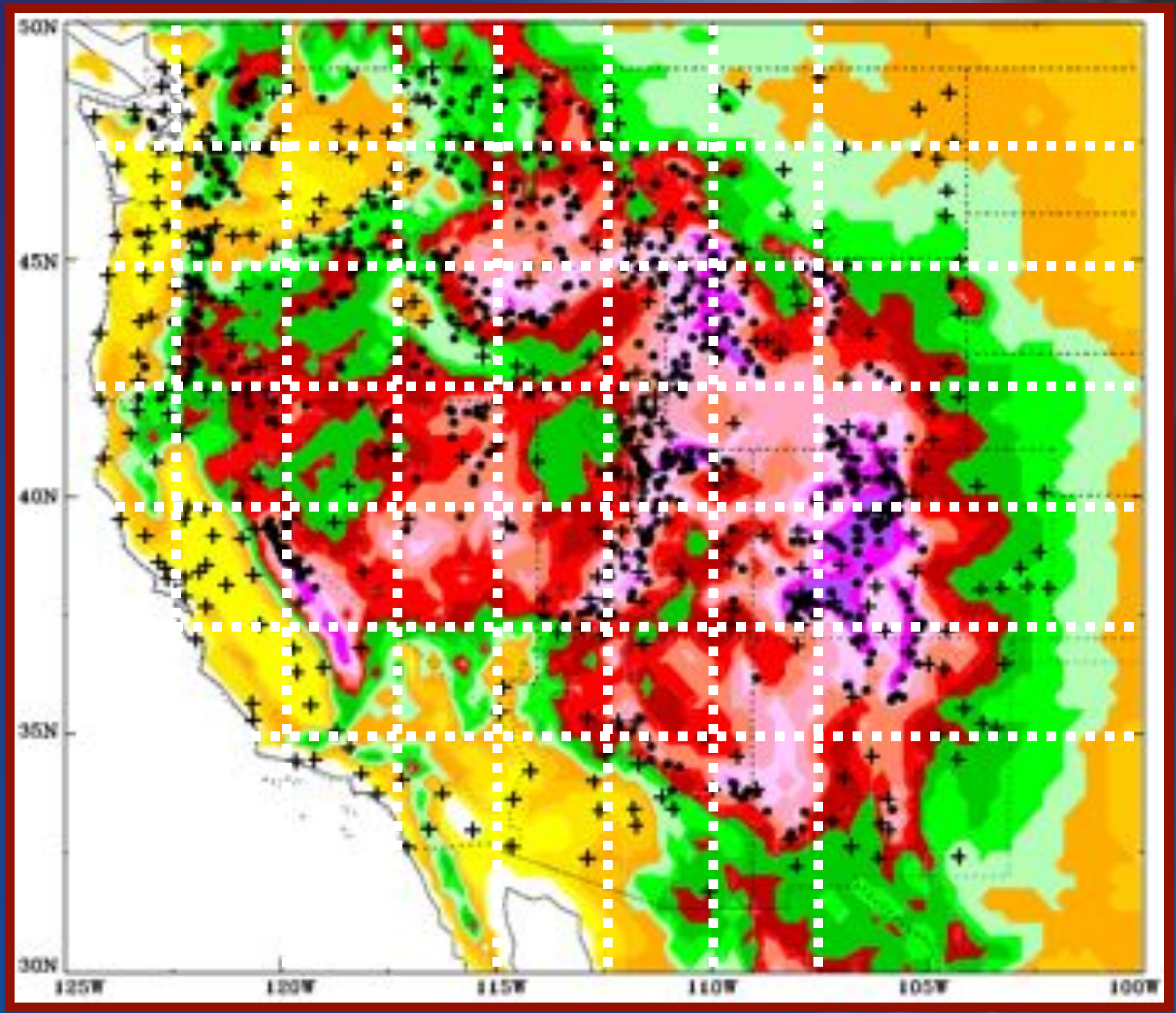
Monthly lapse rate variations derived from daily mean air temperature in 11 western US states. The left panel includes the the eight states in continental-type locations, while the right panel includes three states in maritime-type locations.

$$LR = -\frac{\Delta T}{\Delta Z}$$

Lapse rate is simply defined as the decrease of air temperature with height.

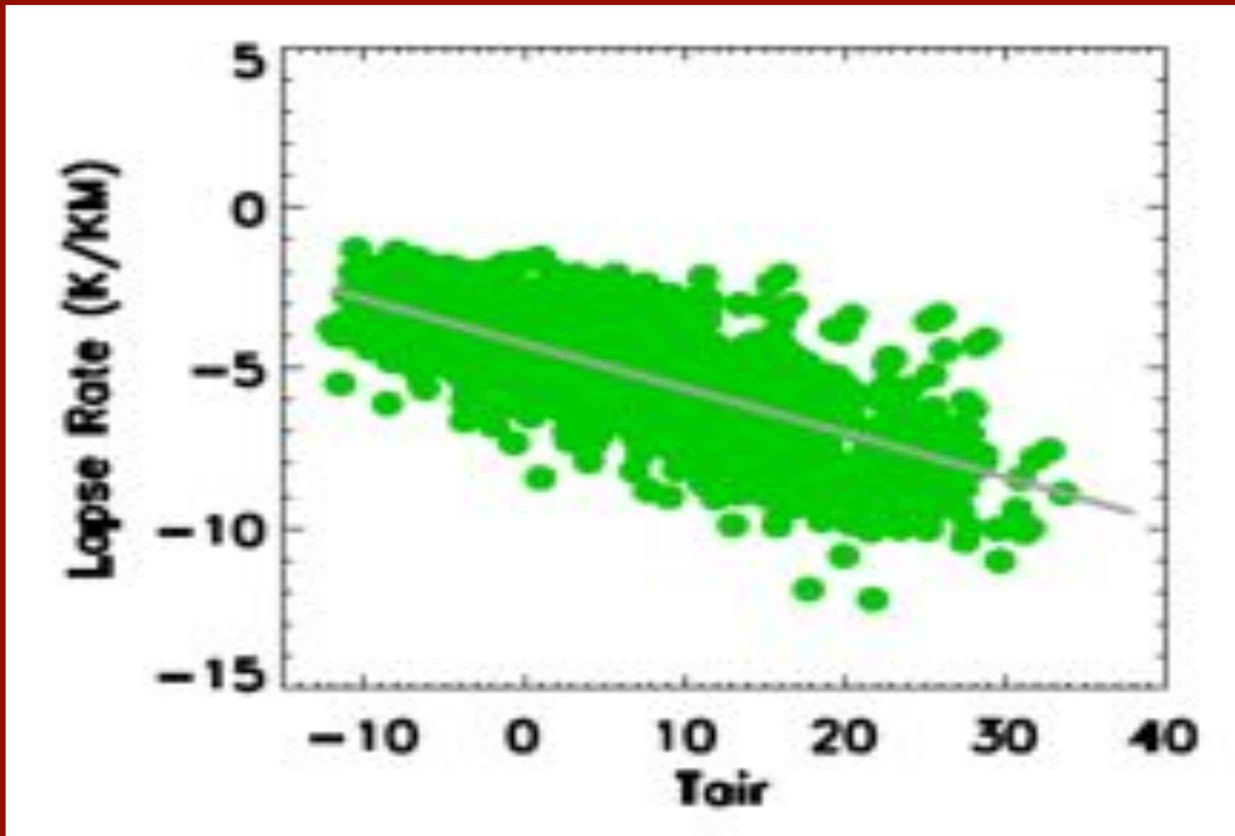
We grouped all available stations into 2.5 degree by 2.5 degree grid boxes. The white dotted lines show the boundaries for each grid box.

Among the 53 boxes over the study domain, the boxes with 5 or more in-situ stations available were selected in the statistical calculation of lapse rate.



The elevation of the western US along with the spatial distribution of the in-situ stations (Dots – SNOTEL and Plus Signs – USHCN).

Relation between Lapse Rate and Air Temperature



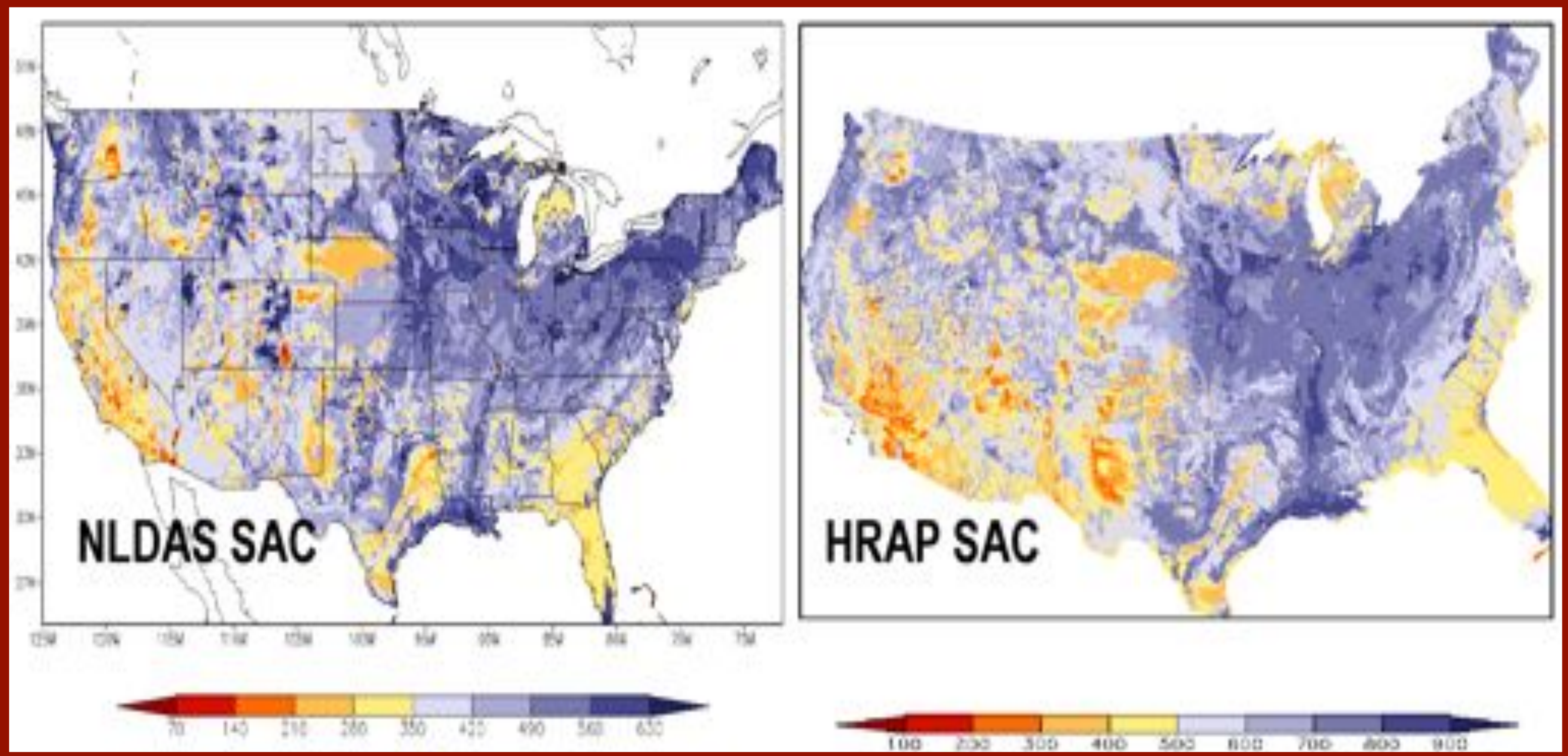
LR = -4.23 - 0.13*Tair

RMSE=1.37

LR=Lapse Rate

The regression equation to predict lapse rate from air temperature was derived using all temperature pooled together, including daily mean, daily minimum, daily maximum temperatures. The derived relationship thus includes the instantaneous variations between the lapse rate and temperature. Future work will study the impact of air humidity on the LR.

Comparison between NLDAS and High-resolution



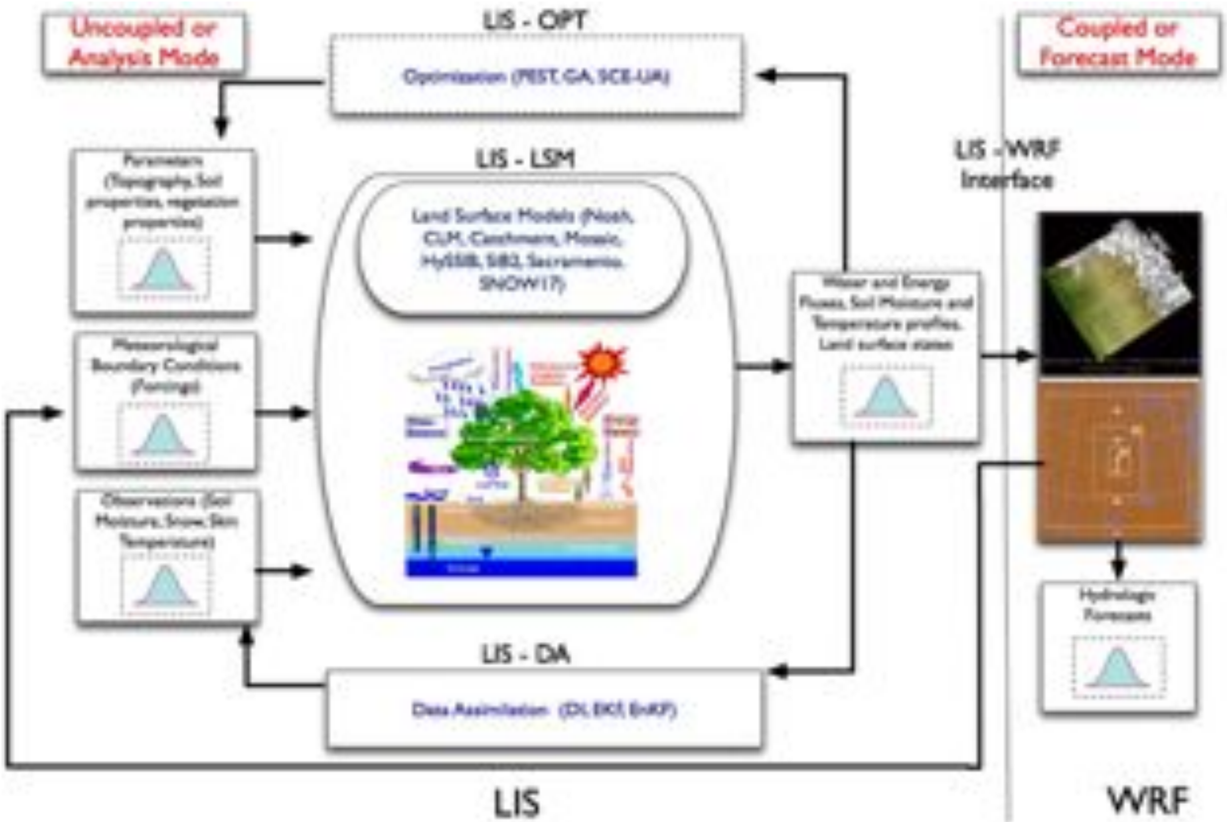
30-year July climatology of total soil moisture over the continental US for the SAC model on the 1/8th degree NLDAS (left) and 4KM HRAP (right) grids.

Conclusions and Future Plan

- Lapse rate research in support of 4km CONUS modeling project is ongoing and nearing completion
  - The lapse rate can be quantitatively predicted from air temperature using a statistical regression equation.
  - The predicted lapse rate will be verified against observed lapse rates derived solely from in-situ measurement within each grid box.
  - We will integrate the derived statistical regression equation into the land surface models to adjust the forcing data (including air temperature) for differences between forcing terrain and model terrain.
  - Other atmospheric variables, such as humidity, will be further investigated for their effect on the spatial and temporal variability of lapse rates
- Remainder of project plan will be executed after lapse rate research is complete
- Project will support drought monitoring through production of long term model climatologies and real-time operations

The Land Information System (LIS)

- LIS is a flexible land-surface modeling and data assimilation framework developed with the goal of integrating satellite- and ground-based observational data products with land-surface models
- LIS can generate improved estimates of land-surface conditions such as soil moisture, evaporation, runoff, snow pack, and surface fluxes



LIS can use many different LSMs, forcings, parameter datasets, observations, and includes modules for data assimilation and parameter optimization techniques. In addition to being run in an offline/uncoupled mode forced by surface datasets, LIS can also be run coupled to the WRF forecast model.

LSMs and Data Assimilation in LIS

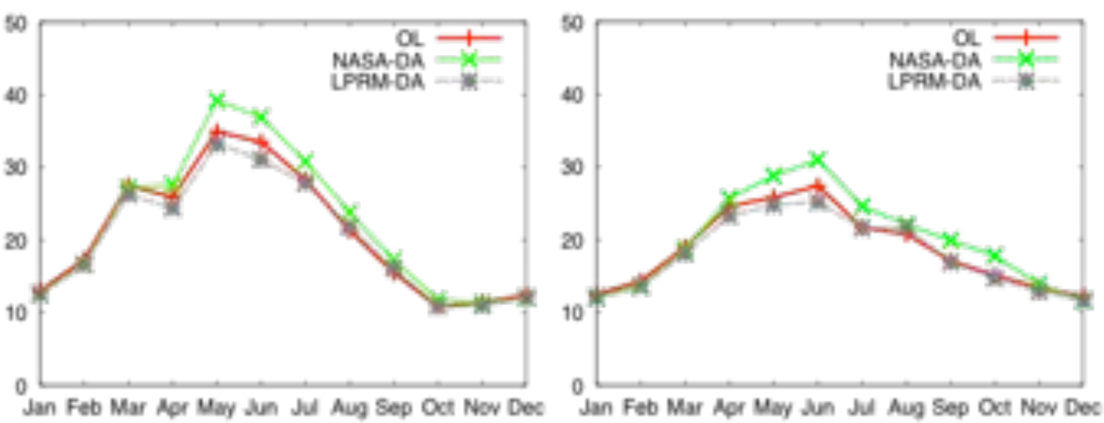
- NLDAS land-surface models (LSMs) will be benchmarked in LIS and upgraded to the latest versions (Noah3.2/3.3/MP, GMAO's Catchment, SAC-HT/SNOW-17, VIC)
- The LIS framework will allow data assimilation of soil moisture and snow products to help improve drought diagnosis (and other water/energy variables) in NLDAS
- Parameters, resolution, and satellite sensors to be used:

Parameters	**Spatial Resolution**	**Satellite Sensors**
Snow covered area (SCA)	500m	Terra/Aqua MODIS
Snow water equivalent	25-km	Aqua AMSR-E
SCA & SWE	25-km	ANSA
Soil moisture	25-km	Aqua AMSR-E

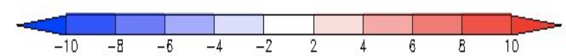
Recent DA results using NLDAS in LIS

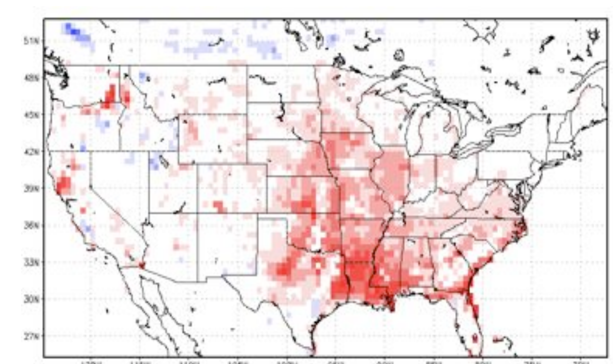
- Peters-Lidard et al. (2011, *Hydrological Processes*, in revision) ran Noah3.2 in LIS using NLDAS-2 forcing data, in an "open-loop" simulation, and in two simulations separately assimilating two different AMSR-E soil moisture products using 7 years of data (2002-2008)
- Monthly gridded evapotranspiration (ET) products from FLUXNET (Jung et al., 2009) and MOD16 (Mu et al., 2011) were used as reference datasets; some improvement was found from using the LPRM (Owe et al., 2008) soil moisture dataset from VU Amsterdam. Units = W/m^2.

Seasonal cycle of the RMSE of ET estimates from using DA of two different SM products and the run without DA (in red) compared to FLUXNET (left) and LPRM (right)



ET improvement using LPRM DA [RMSE(OL) – RMSE(DA)] with FLUXNET as reference for spring (MAM)





LDAS data/services at the NASA GES DISC

- Hydrology DISC (HDISC) http://disc.gsfc.nasa.gov/hydrology/
- NASA/GSFC NLDAS website: http://ldas.gsfc.nasa.gov/nldas/

32+ years of hourly NLDAS and 3-hourly GLDAS data sets available at the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC)

Data is available via 4 methods: Mirador search/subset/downloading, Giovanni online visualization and analysis, anonymous ftp, and a GDS. Data also available via EPA BASINS and CUAHSI HIS HydroDesktop.

Data Type (Short Name)	Description	FTP	GDS	Mirador Navigation	Mirador Search
NLDAS-1, 0.125 degree, North America					
NLDAS_FOA0125_H.001	Hourly forcing	✔	✔	✔	✔
NLDAS-2, 0.125 degree, North America					
NLDAS_FORA0125_H.002	Hourly primary forcing	✔	✔	✔	✔
NLDAS_FORB0125_H.002	Hourly secondary forcing	✔	✔	✔	✔
NLDAS_MOS0125_H.002	Hourly Mosaic	✔	✔	✔	✔
GLDAS-2, 1.0 degree, Global					
GLDAS_NOAH10_3H_E1.002	3 hourly Noah experiment 1	✔	✔	✔	✔
GLDAS_NOAH10_M_E1.002	Monthly Noah experiment 1	✔	✔	✔	✔
GLDAS-1, 0.25 degree, Global					
GLDAS_NOAH025SUBP_3H	3 hourly Noah	✔	✔	✔	✔
GLDAS_NOAH025_M	Monthly Noah	✔	✔	✔	✔
GLDAS-1, 1.0 degree, Global					
GLDAS_CLM10SUBP_3H	3 hourly CLM	✔	✔	✔	✔
GLDAS_CLM10_M	Monthly CLM	✔	✔	✔	✔
GLDAS_MOS10SUBP_3H	3 hourly Mosaic	✔	✔	✔	✔
GLDAS_MOS10_M	Monthly Mosaic	✔	✔	✔	✔
GLDAS_NOAH10SUBP_3H	3 hourly Noah	✔	✔	✔	✔
GLDAS_NOAH10_M	Monthly Noah	✔	✔	✔	✔
GLDAS_VIC10_3H	3 hourly VIC	✔	✔	✔	✔
GLDAS_VIC10_M	Monthly VIC	✔	✔	✔	✔